USSN: 09/986,828
Art Unit: 2874

Remarks

The applicants have deleted reference to the slab waveguide since this forms no direct part in the invention, which relates to the configuration of the facets of the grating. A planar waveguide grating typically includes a slab waveguide inherently. Since express mention of the slab waveguide has been removed from the claims, a drawing amendment is believed no longer to be required.

The applicants have added a paragraph on page 3 indicating the nature of the units in Figures 1 to 3. Support is found on page 6, where there is reference to a 16 facet grating, which is shown in Figures 1 and 2. It can be seen by inspection that the facet size is about 150 microns.

Claims 1 and 8 have been amended to make it clear that each grating facet forms the arc of an ellipse with foci at the input and pre-selected output channel respectively. Support for this feature is found in Figure 4 and the accompanying explanation on page 5.

With regard to the rejection under 35 USC 102(e), a feature of the invention is that the facets (or at least groups of facets) effectively have an <u>elliptical</u> curvature having a first focal point at an input channel and a second focal point at a selected output channel. An ellipse has the property that any ray striking its surface from one focus with pass through the second focus. This makes the facets astigmatic with respect to the two focal points. Thus, the applicants ensure that wherever the light ray from the input channel strikes a particular facet it will be directed to the selected output channel. This arrangement results in the reduction in higher order aberrations that occur as a result of the use of straight facets employed in conventional gratings.

The Examiner cites He as allegedly showing elliptical facets under 35 USC 102(e) in view of the fact that He was published on September 19, 2002, namely after the applicant's filing date of November 13, 2001. He's full patent application has a filing date of March 15, 2002, which is also <u>subsequent</u> to the applicant's filing date.

He claims priority under 35 USC 119(e) from US provisional application no. 60/276,205 filed on March 16, 2001. However, in order to be entitled to priority under 35 USC 119(e), "the specification of the provisional application must satisfy written description requirement of 35 U.S.C. §112 for the invention claimed in the non-provisional application". See, *New Railhead Manufacturing LLC v. Vermeer Manufacturing Co.*, 63 USPQ2d 1843 (CA FC 2002), where the

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court held that the claim limitation at issue, namely, specific angled relationship between drill bit and its housing, was not adequately described in the provisional application.

The Examiner will also note that 35 USC 119 (e) provides that the non-provisional application is only entitled to the benefit of the filing date of the provisional application "as to such invention" that is disclosed in accordance with the requirements of 35 USC 119(e).

The applicants are submitting herewith a copy of provisional application No. 60/276,205 obtained from the US patent office. Upon reviewing this specification, the Examiner will note that this specification is completely silent as to the use of elliptical facets as claimed in the present application. At page 6, line 9, this specification indicates that the grating facet is "curved" to "more accurately separate the closed spaced channels", but there is no indication as to the nature of this curvature or any explanation as to how such curvature might increase "spectral finesse".

Consequently, in the applicant's respectful submission, He is not entitled to the priority date of the provisional application in respect of any teaching relating to the use of elliptical facets. Since his effective filing date for any such teaching is subsequent the applicant's filing, date He is not a citable reference under 35 USC 102(e) in respect of such teaching.

To the extent that He is a citable reference, such citability only relates to the teaching of curved facets, not facets of elliptical curvature. The expression "curved" covers an infinite variety of non-linear shapes. Any non-linear continuous line is *curved*. It is well established that in order to constitute an anticipation under 35 USC 102, a prior art reference must be enabling as required under 35 USC 112, first paragraph. The mere disclosure of curved facets is not enabling with respect to the use of elliptical facets having their foci arranged as defined in the claims. This elliptical arrangement as claimed in the present application results in considerable reduction in aberration at high orders as explained in the present application, and which would not occur with curved facets of some arbitrary shape that were not effectively ellipses.

The present invention cannot be considered obvious over He's teaching of curved facets. Not only is this teaching non-enabling, there would be no motivation for one skilled in the art to make the facets arcs of an ellipse as defined in the present claims without using the applicant's teachings as a blueprint, something that is expressly forbidden by the case law.

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Reconsideration and allowance are respectfully requested.

Respectfully submitted,

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UNITED STATES PATENT AND TRADEMARK OFFICE
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Transmittal

1

Level - 2
Version 1.1

03/16/01 JC772 U.S. PTO

JC997 U.S. PTO 60/276205

PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

INVENTOR(S)

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☐ Additional inventors are being named on the sheet attached hereto.

TITLE OF THE INVENTION (280 characters max)

INTEGRATED OPTICAL INTERLEAVER/DE-INTERLEAVER

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ENCLOSED APPLICATION PARTS (check all that apply)

☒ Specification — Number of pages: 10

☒ Drawing(s) — Number of Sheets: 4

☐ Other — (Specify):

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

☐ Applicant claims small entity status. See 37 CFR 1.27.

☐ A cheque is enclosed to cover the filing fees.

☒ The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number: 50-1142

FILING FEE AMOUNT (4): $75.00

Respectfully submitted,

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DATE: March 16, 2001

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Integrated optical interleaver/de-interleaver

Field of the Invention

This invention relates generally to wavelength division multiplexing and more particularly to an integrated waveguide grating based optical device capable of interleaving and de-interleaving different wavelength channels.

Background of the Invention

The rapid adoption of the Internet has resulted in a need to provide large amounts of bandwidth over long distances. To accomplish this optical networks have been deployed all over the world. The amount of information that a single fiber optic cable can carry is typically boosted using wavelength division multiplexing (WDM). This technique allows many different wavelengths of light to travel over the same fiber. Many different DWDM technologies have been developed, including integrated waveguide demultiplexers based on phased array waveguide gratings (AWG) and etched echelle grating-on-a-chip spectrometers. The integrated devices have many advantages such as compactness, reliability, reduced fabrication and packaging costs, and potential monolithic integration with active devices of different functionalities.

However, fine spectral finesse is often difficult to achieve using low cost easy to manufacture optical components. Therefore, there is a common practice of de-interleaving optical signals to produces two or more signals each having a number of signals within different wavelength channels spaced apart further than the wavelength channels within the original signal. For example, channels 1, 3, 5, 7, and 9 are provided to a first output port and channels 0, 2, 4, 6, and 8 are provided to a second other output port. Now, the DWDM component requires less stringent requirements on passband width and on slopes of passband edges.

A wavelength range of a WDM system is determined by the optical amplifiers used in the transmission line. Currently the most commonly used amplifiers are erbium-

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doped fiber amplifiers (EDFA). The wavelength windows are from 1530nm to 1565nm (C-band) and from 1570nm to 1610nm (L-band). Each of the wavelength windows can accommodate about 40 channels with 100GHz (~0.8nm) spacing, or 80 channels with 50GHz (~0.4nm) spacing. An interleaver for use in reducing spectral finesse of DWDM components would operate within these same bands.

Object of the Invention

It is an object of the invention to provide a waveguide grating based component capable of performing interleaving functions.

Summary of the Invention

In accordance with the invention there is provided an optical device comprising:
an input port for receiving an multiplexedoptical signal including optical signals within each of a plurality of wavelength channels having a predetermined channel spacing;
N output ports wherein N>1;
An echelle grating for separating the multiplexed optical signal received at the input port in dependence upon wavelength to provide a plurality of channelised signals to each of the output ports;
wherein optical signals corresponding to each of a plurality of aN+1th optical channels are provided to a same first output port, and
optical signals corresponding to each of a plurality of aN+2th optical channels provided to a same second output port,
wherein a is a whole number 0<=a.

Brief Description of the Drawings

Fig. 1 is a prior art schematic diagram of an etalon de-interleaver device.

Fig. 1b is a prior art schematic diagram of a curved reflective diffraction grating interleaving device.

Figure 2 is a simplified graph of wavelength channels and the wavelength response of an interleaver.

Figure 3 is a simplified schematic diagram of an implementation of the invention featuring a curved reflective diffraction grating.

Fig. 4 is a simplified diagram of a portion of an echelle grating for use in providing interleaving functionality.

Figure 5 is a simplified diagram in high magnification of a grating facet.

Figure 6 is a simplified diagram of grating facets with curved geometrics.

Figure 7 is a simplified diagram of grating facets with stepwise curved geometries.

Fig. 8 is a simplified diagram of a grating with two angular faces to improve total internal reflection of light incident thereon.

Figure 9 is a simplified diagram of grating facets similar to those of Figure 8 but having curved geometries.

Detailed Description of the Invention

In order to overcome the limitations of the prior art, according to the invention there is provided an interleaver having an echelle grating with a high diffraction order and a cyclic response cycling over a plurality of wavelength channels within a known application window.

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Referring to Fig. 1a, an etalon based interleaver is shown. The etalon comprises an optical cavity 1 disposed between two partially reflective surfaces 2a and 2b. Preferably, the reflective surfaces are around 95% reflective. In the surface 2a is an input port 2c for receiving interleaved optical signals. The received light reflects within the cavity with a portion of the light exiting on the exit face 2b. The exiting light is focussed using a lens 3 into each of two optical fibres 4a and 4b. In use, light at wavelengths λ_0 λ_2 λ_4 λ_6 are all provided to optical fibre 4a and light at wavelengths λ_1 λ_3 λ_5 λ_7 are all directed to optical fibre 4b. Thus, as is the function of a de-interleaver, the channel spacing within the optical signals in the fibres 4a and 4b is twice that in the interleaved signal. Of course, the etalon is designed to support accurate separation of the received optical signal into two de-interleaved optical signals.

Evidently, the above device relies on a dispersive element having a small free spectral range (FSR) such that a first channel is directed to a first port and a second channel is directed to a second port and a third channel is directed to the first port and so forth. illustrated in Fig. 1.

Figure 2 shows graphically typical behavior of the device according to prior art, described by the spectral response, i.e., the transmission coefficient of each channel as a function of wavelength. In this example, the device separates eight wavelength channels within an EDFA application window into two de-interleaved signals. The device separates each of four bands into two channels and directs all first channels to a same output port with approximately a same power and all second channels to a second output port with approximately a same power.

In integrated optical grating technology including echelle gratings, echelon gratings, and array waveguide gratings a dispersive and focusing component including an array of optical elements is provided. Each of these elements introduces a slightly different optical path length for a beam traveling from an input to an output port. In an etched grating, this optical element is a reflecting mirror (grating facet) whereas in the case of an AWG, it is an optical waveguide. A grating with a high diffraction order is used so that the free spectral range of the grating is large enough to contain all the

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wavelength channels to be interleaved or de-interleaved within the overall wavelength window of the network application.

Though an echelle grating is substantially more compact than an array waveguide grating and, therefore, requires less material to produce. The grating facets become very large with reduced free spectral range resulting in substantially different path lengths for light reflecting from a same facet and, as such, decreases performance. Therefore, typical echelle grating based applications are thought to provide only so much spectral finesse insufficient for most interleaver applications.

Figure 3 illustrates the overall spectral response curves of a simple implementation of a grating based interleaver device supporting multiple de-interleaved output ports according to a first embodiment of the invention. In this embodiment, the free spectral range of the device is substantially equal to the channel spacing multiplied by the number of output ports. For example, to de-interleave a signal into two signals, the grating is provided with an FSR of two channel widths. All channels within an application window are de-interleaved using the same device. As shown in Fig. 3, an integrated optical component 30 is shown having a single input port 31 and two output ports 32a and 32b. A dispersive element in the form of an echelle grating 33 is disposed optically between the input port 31 and the output ports 32a and 32b for directing light from the input port 31 to the output ports 32a and 32b. The dispersive element has an FSR equal to the width of the two adjacent channels for a true de-interleaver. Alternatively, the device is for de-interleaving channels that are proximate one another but a known spacing from a next pair of channels in which case the FSR is a wavelength distance between the first channel in a first pair and the first channel in a second adjacent pair.

Referring to Figure 4, an echelle grating 41 for use as the dispersive element is shown. Unfortunately, when channel spacing is close together, for example for 50GHz spacing, the size of the grating facets 42 becomes large. As the grating facet 42 size increases, error due to varied path length and variations in the angles α_1 and α_2 to and

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from each facet surface results. That said, even for closely spaced channels, an echelle grating can be used to de-interleave them.

Referring to Figure 5, a portion of the echelle grating 31 is shown. As is evident, the light signal 51 experiences differences in phase and angle when reflected from the facet 52 depending on where it impinges on the facet surface. In order to correct for these errors, grating facets are modified according to Fig. 6.

In Fig. 6, a modified grating facet 61 is shown wherein the facet is curved to more accurately separate closely spaced channels. Alternatively, as shown in Fig. 7, the facets 71 are stepwise curved facilitating design and manufacture by eliminating curved surfaces. By reflecting light from the curved or stepwise curved surfaces increased spectral finesse results.

Referring to Figure 8, another grating geometry is shown. Here planar facet faces are replaced by a V groove such that light incident on one face of the V is reflected toward the other face and then reflected off the facet. In this way, without coating each facet with reflective material and by selecting index differences across a facet, total internal reflection of light improves the efficiency of the overall device. Such a geometry has similar drawbacks to other planar geometries and, as shown in Figure 9 a curved geometry for the planar facets of each V groove improves the spectral finesse. Of course, a stepwise curved facet is also possible for implementing the embodiment of Figure 9.

The device according to the simple implementation of the first embodiment of the invention with more than two channels is limited in that since the full free spectral range of the grating is used for de-interleaving the channels, the loss non-uniformity, i.e. the loss difference between the central channel and the channels at the free spectral range edge can be as large as 3 dB, which is undesirable in many applications. As shown in the example of Figure 6 wherein de-interleaving separates the interleaved signal into four signals, each pair of outside channels within a four-channel band experience more attenuation than the two central channels.

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Since the grating device is bi-directional, it is optionally used as an interleaver or a demultiplexer. The cyclic behavior of the device according to the present invention is also implementable in integrated interleaver and de-interleaver device based on a single grating. Such a device operates on a same principle as the multiplexer and demultiplexer using a same grating, as is disclosed in U.S. patent application filed on March 06, 2001 entitled Bidirectional Multiplexer and Demultiplexer Based On A Single Echelle Waveguide Grating in the name of the present inventors and incorporated herein by reference.

An advantage of the invention is that as further bandwidth becomes needed to support data communication, interleaving and de-interleaving is supported and is matched across the increased bandwidth. Thus, the invention is compatible with expandable systems.

Clearly, most optical devices are bi-directional and, as such, input ports for interleavers are otherwise labeled output ports for de-interleavers and so forth.

It is apparent to those skilled in the art that modifications and alternative embodiments can be made without departing substantially from the teachings of the invention.

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Claims

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Claims

What is claimed is:

1. An optical device comprising:
an input port for receiving an multiplexed optical signal including optical signals within each of a plurality of wavelength channels having a predetermined channel spacing;
N output ports wherein $N>1$;
An echelle grating for separating the multiplexed optical signal received at the input port in dependence upon wavelength to provide a plurality of channelised signals to each of the output ports;
wherein optical signals corresponding to each of a plurality of $aN+1$th optical channels are provided to a same first output port, and
optical signals corresponding to each of a plurality of $aN+2$th optical channels provided to a same second output port,
wherein a is a whole number $0<=a$.

2. An optical device according to claim 1 wherein $N=2$.

3. An optical device according to claim 1 wherein $0<=a<=5$.

4. An optical device according to claim 1 wherein the echelle grating comprises a plurality of etched facets, each facet having blaze angle and a planar surface and the facets arranged along a smooth curve forming an approximately stepwise curve.

5. An optical device according to claim 1 wherein the echelle grating comprises a plurality of etched facets, each facet having a curved surface and the facets arranged along a smooth curve forming an approximately stepwise curve.

6. An optical device according to claim 1 wherein the echelle grating comprises a plurality of etched facets, each facet having a plurality of facets having planar surfaces

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and defining an approximately stepwise curve, the plurality of facets defining a second other approximately stepwise curve having a different radius of curvature.

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Abstract

6

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Abstract of the disclosure

A grating based optical de-interleaver useful over a wide wavelength range is presented. The spectral response of the device is cyclic. The free spectral range of the grating is designed to separate wavelength channels to be de-interleaved. This device, being bi-directional will also operate as an interleaver.

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Drawings

7

Level - 2
Version 1.1

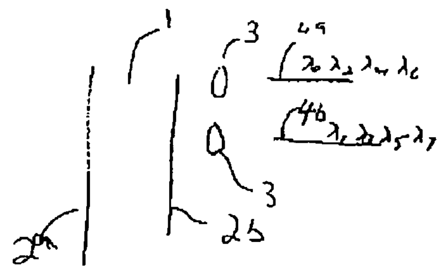

Fig. 1

Fig. 2

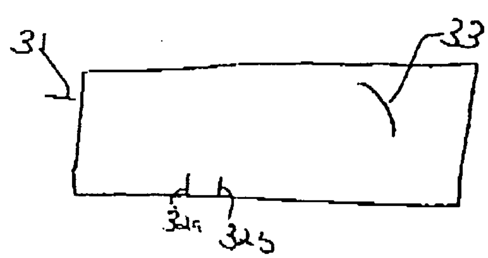

Fig. 3

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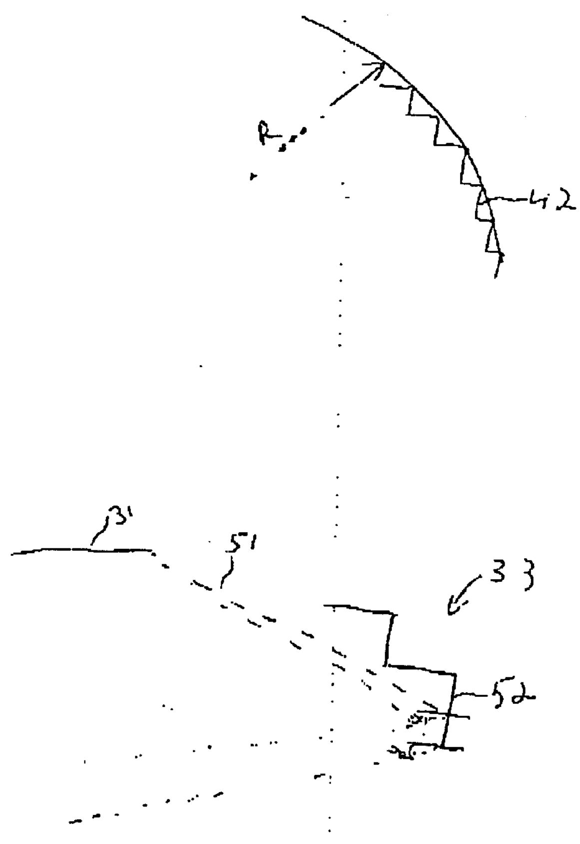

Fig. 5

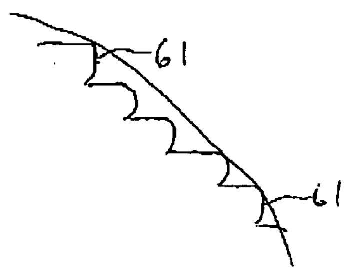

Fig. 6

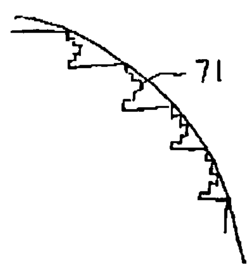

Fig. 7

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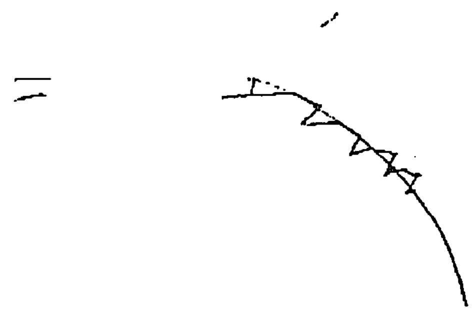

Fig. 8

Fig 9

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